Bio-economic evaluation and optimization of livestock intensification in the Central Highlands of Vietnam

Birthe Paul
Celine Birnholz
Adrian Bolliger
Truong Tan Khanh
Jeroen Groot

B.Paul@cigar.org

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Outline

- Introduction
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  - Household modeling
- Results
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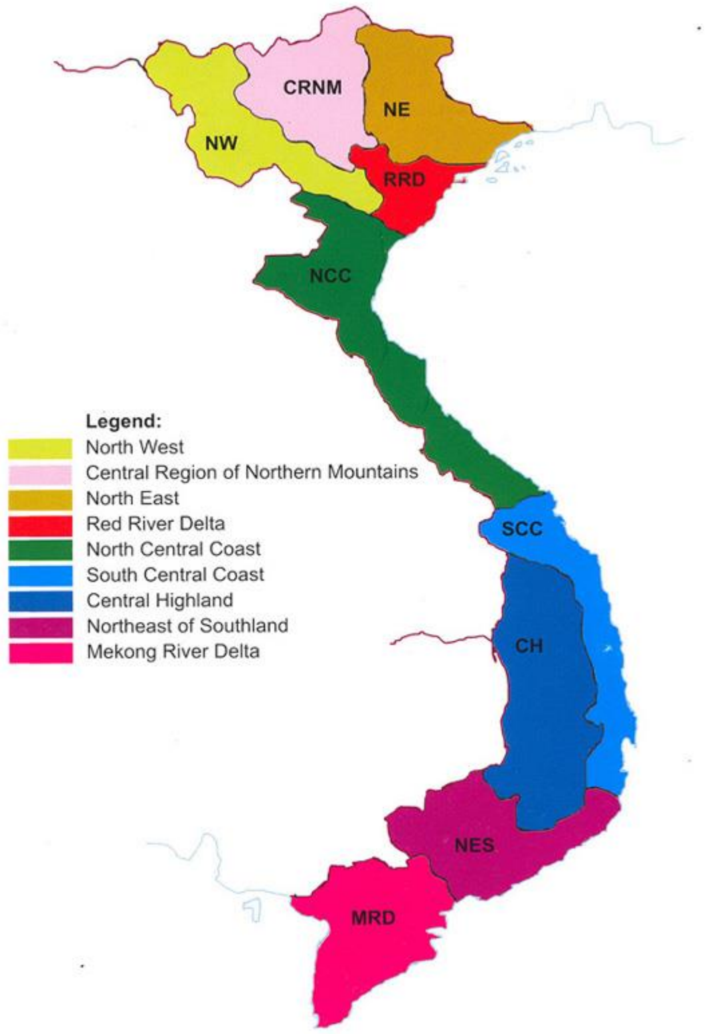
  - Livestock intensification scenarios
  - Optimization
- Conclusions

Introduction – Central Highlands

- Until mid-1970s, Central Highlands of Vietnam inhabited by ethnic minority groups under shifting cultivation, hunting and gathering
- After end of Vietnam war in 1975, over ½ million ethnic Kinh were moved from densely populated Red River Delta to Central Highlands
- 1981 ban of slash-and-burn agriculture, and in 1986 economic and land reforms leading to sedentary ag
- Especially coffee boomed in the 1990s (20% annual growth), leading to influx of immigrants, doubling population
- However, acidic and infertile soils together with falling world market prices led to decreasing profits -> smallholders looking for alternatives

Map of agro-ecological zones of Viet Nam



Introduction – project history

- Dak Lak local government encourages development of beef value chains as domestic demand is not yet met by local production
- Traditionally livestock kept as insurance, and fed on natural grasses/shrubs, crop residues, forest grazing -> low body weight, low reproductive performance, low commercialization
- Increasing population pressure in Ea Kar put pressure on communal feed resources
- In 2000, CIAT partners with Tay Nguyen University (TNU) and others for first 'Forages for Smallholders Project' in Ea Kar in Dak Lak province.
- By 2010, over 1/3 of the Ea Kar district population (>3000 smallholders) had started growing forages, 500 households fattening for market, more improved breeds (Laisind)
- Imported feeds also on the rise, including soybean from LAC

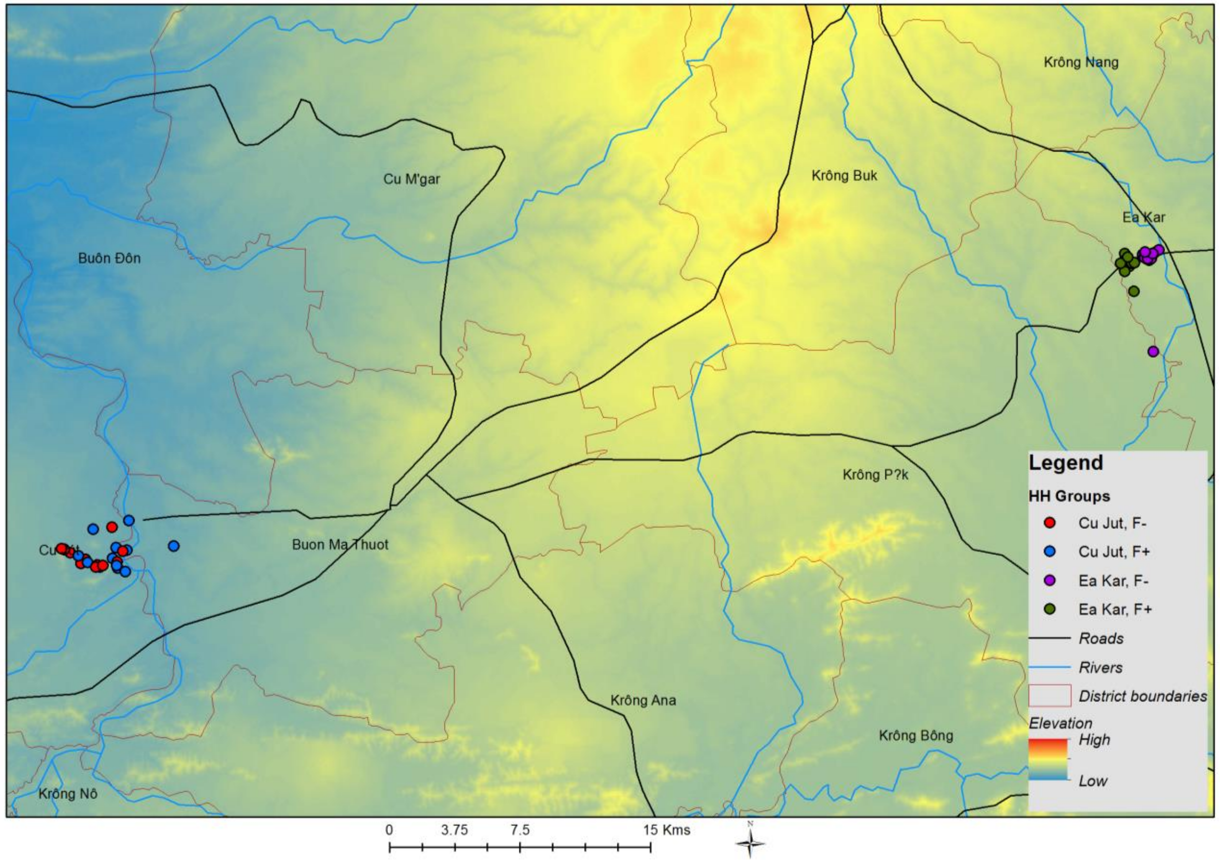
Introduction – environmental trade-offs

- However, livestock intensification comes at trade-off with the environment (land use, land degradation, GHG emissions, biodiversity…)
- *Ex-ante* impact assessment and quantitative household modeling can assist in prioritizing interventions that contribute to sustainable intensification
- Systematic exploration of trade-offs is still rare

Introduction – study objectives

- This study aims to
  1. Explore the diversity of smallholder farms in the Central Highlands of Vietnam;
  2. Quantify bio-economic performance of contrasting farms;
  3. Explore management alternatives and trade-offs through optimization modeling.

M&M: Study sites



Ea Kar in Dak Lak province

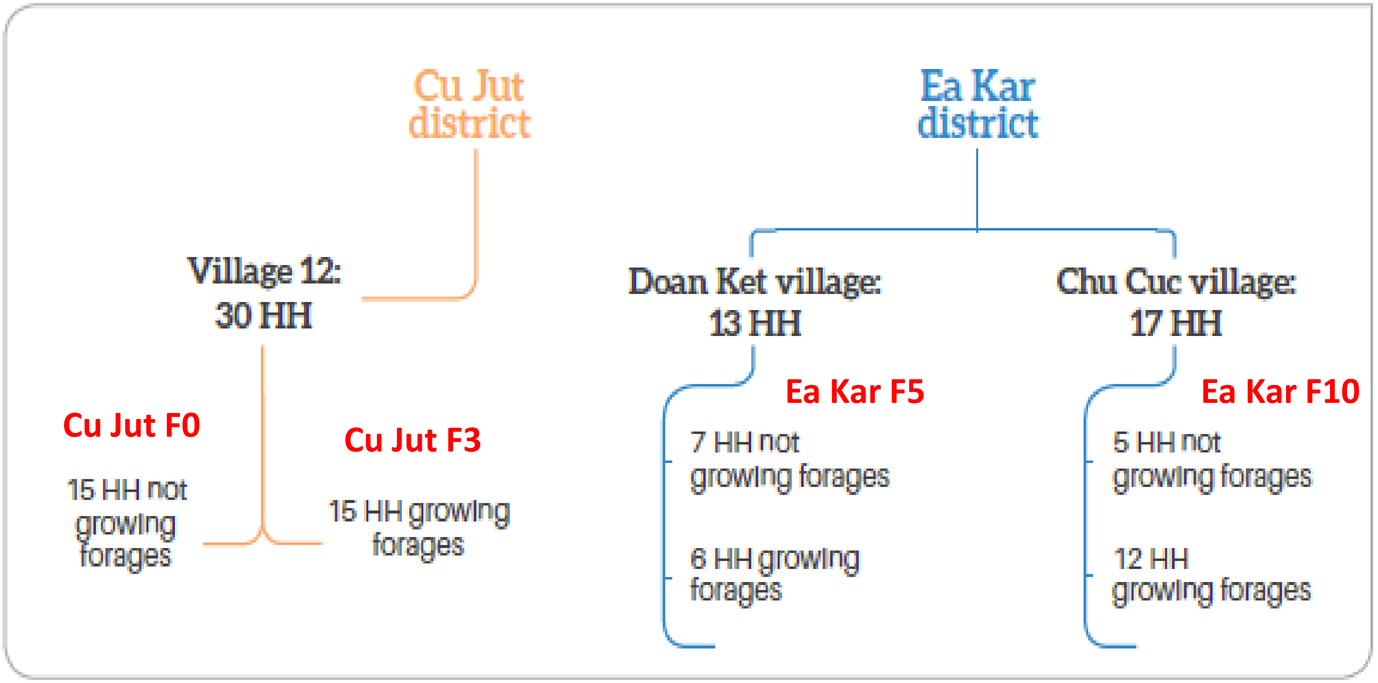
- Kinh more present, high population pressure
- Forage projects since 2000s
- Livestock intensification advanced
- Coffee

Cu Jut in Dak Nong province

- More Ede than Kinh, lower population pressure
- Forage projects since 2012
- Cash crops (pepper, cashews) more dominant

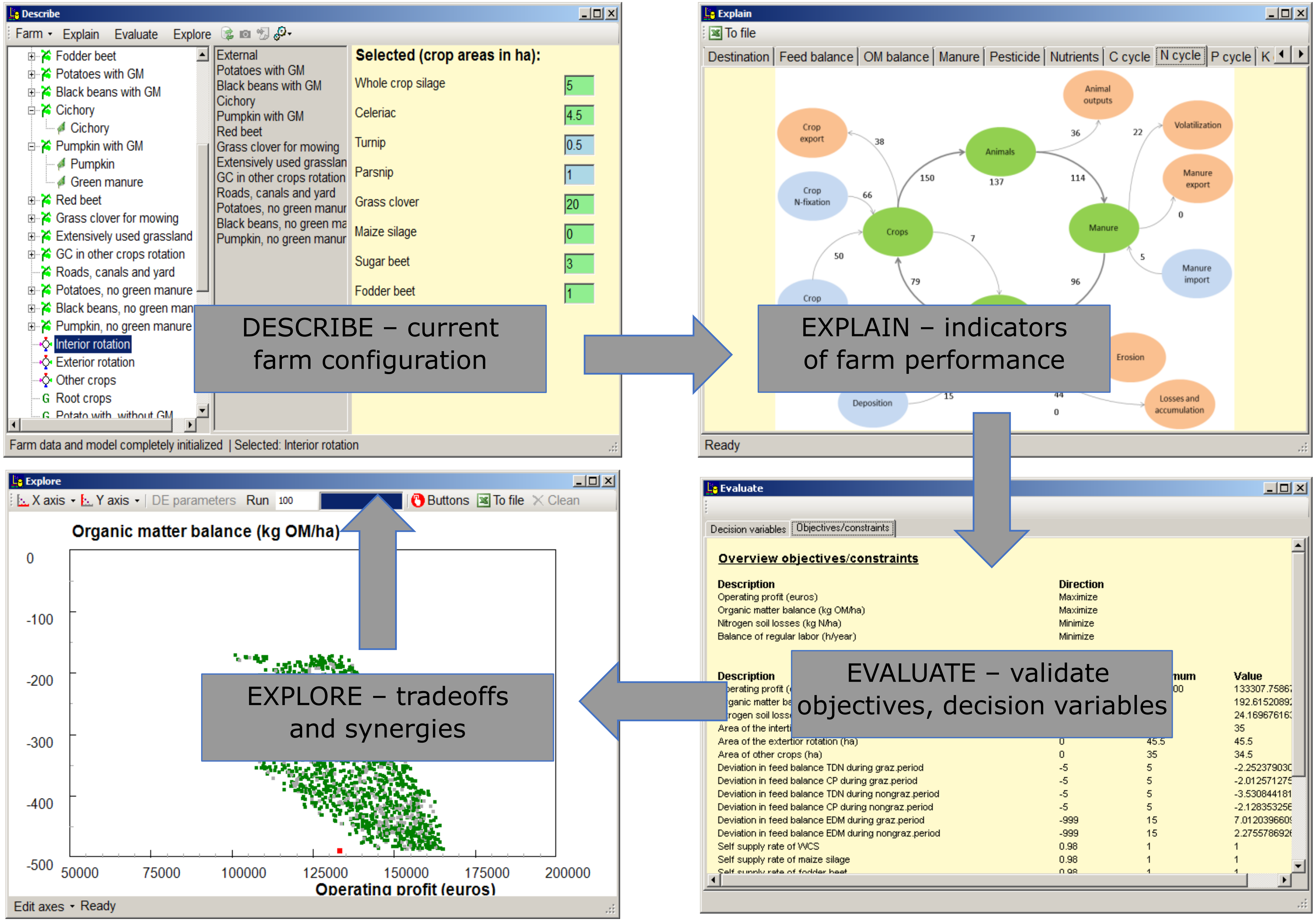
M&M: data collection

- CCAFS funds end of 2014 -> data collection in 60 households in December/January 2014/2015 in the Central highlands using ImpactLite questionnaire
- Soil samples collected from each field -> 276 samples analyzed at TNU
- Field visits/validation November 2015

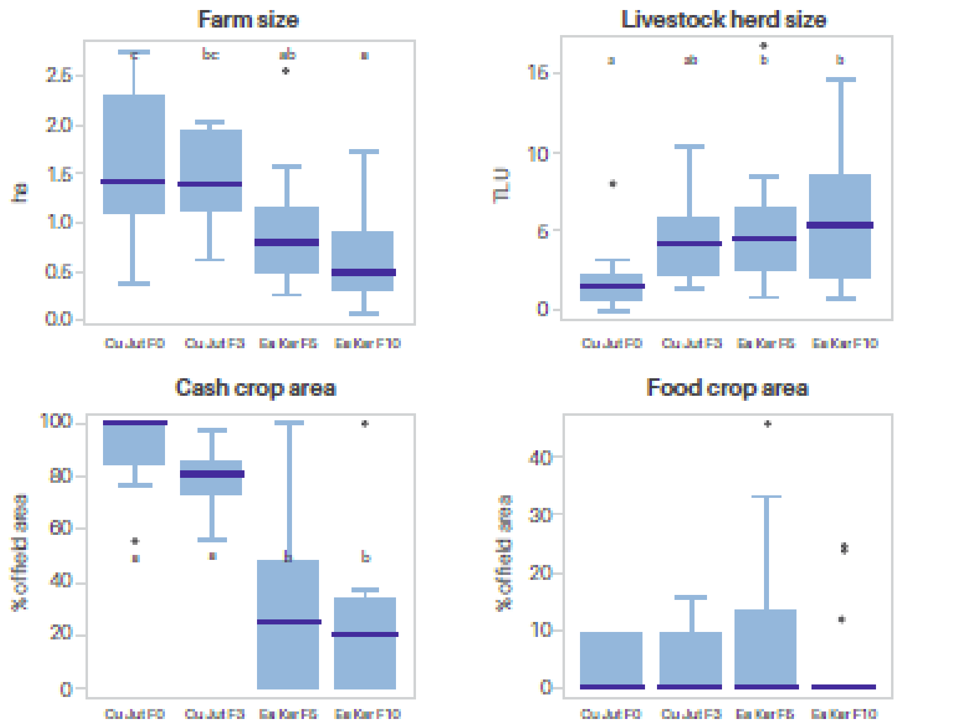


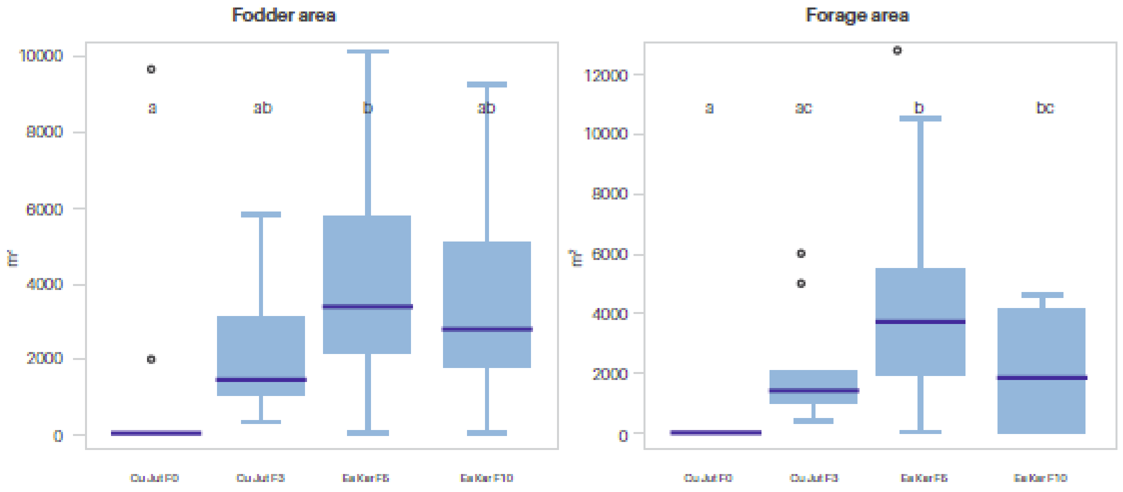
M&M: household modeling

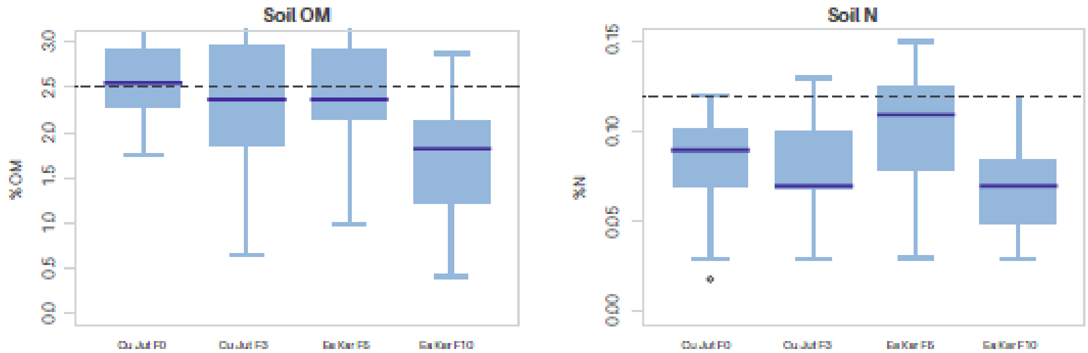
1. Whole dataset analyzed with R to explore farming systems diversity
2. Two farms (one per site) modeled in FarmDESIGN, and bio-economic baseline performance compared
3. Two intensification scenarios (grain-based and forage-based) implemented and impacts compared for Ea Kar farm
4. Ea Kar farm optimized and trade-offs explored

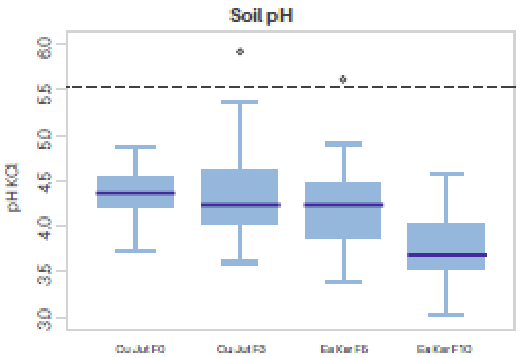

DESCRIBE – current farm configuration
EXPLAIN – indicators of farm performance
EVALUATE – validate objectives, decision variables
EXPLORE – tradeoffs and synergies
Describe
Farm Explain Evaluate Explore
Selected (crop areas in ha):
Whole crop silage
Celeriac
Turnip
Parsnip
Grass clover
Maize silage
Sugar beet
Fodder beet
Farm data and model completely initialized | Selected: Interior rotation
Explain
To file
Destination Feed balance OM balance Manure Pesticide Nutrients C cycle N cycle P cycle K
Animal outputs
Crop export
Animals
Volatilization
Manure export
Crop N-fixation
Crops
Manure
Manure import
Erosion
Deposition
Losses and accumulation
Ready
Explore
X axis Y axis DE parameters Run 100 Buttons To file Clean
Organic matter balance (kg OM/ha)
Operating profit (euros)
Edit axes Ready
Evaluate
Decision variables Objectives/constraints
Overview objectives/constraints
Description
Direction
Operating profit (euros)
Maximize
Organic matter balance (kg OM/ha)
Maximize
Nitrogen soil losses (kg N/ha)
Minimize
Balance of regular labor (h/year)
Minimize
Value
Area of the exterior rotation (ha)
Area of other crops (ha)
Deviation in feed balance TDN during graz.period
Deviation in feed balance CP during graz.period
Deviation in feed balance TDN during nongraz.period
Deviation in feed balance CP during nongraz.period
Deviation in feed balance EDM during graz.period
Deviation in feed balance EDM during nongraz.period
Self supply rate of WCS
Self supply rate of maize silage

Results – farming system diversity









Results – bio-economic baseline I

Cu Jut case study farm

- 5 household members, 3 providing labour
- 2.7 ha – cashew (0.7 ha), rice (0.25 ha), soybean (1.05 ha), non-productive pepper (0.5 ha), catfish (0.15 ha)
- Cashew and soybean sold 100%, rice sold 10%, catfish sold 90%
- Fertilizers: Cashew 142 kg DAP/ha, 57 kg postash/ha, 214 kg N/ha; rice 300 kg DAP/ha; soybean 143 kg/ha
- Crop residues burnt
- 70 chicken and feeder-finisher swine production purely fed on purchased concentrates
- Manure was used for biogas, not fertilizer
- Off-farm job

Ea Kar case study farm

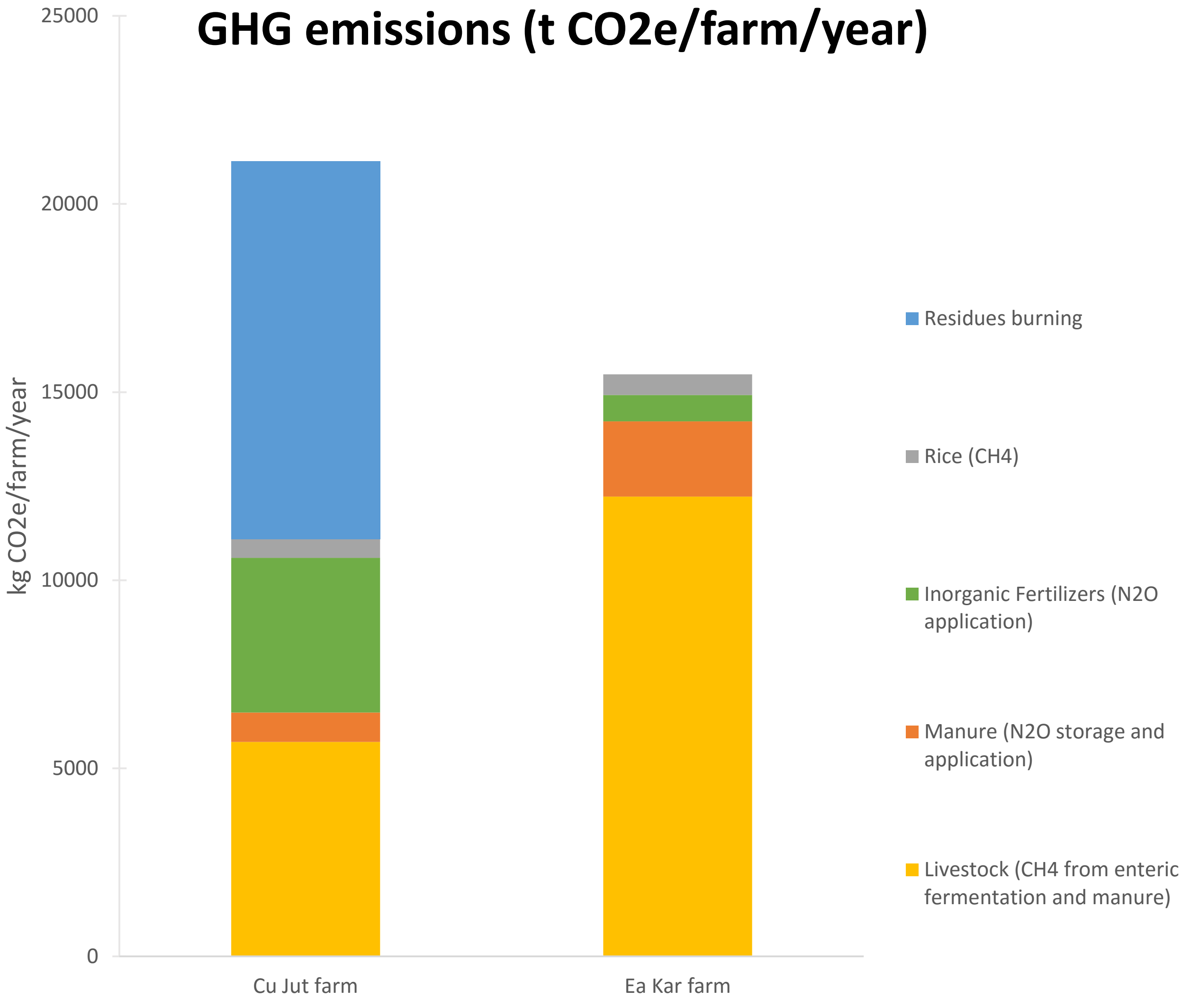
- 4 household members, only 1 providing labour
- Hire labour for specific crop activities
- 1.7 ha – Napier (0.3 ha), coffee (0.5 ha), maize (0.7 ha), rice (0.2 ha)
- Napier and maize 100% fed to livestock, rice for home consumption
- Fertilizers: maize NPK 200 kg/ha; rice 300 kg NPK/ha, Napier 400 kg NPK/ha, coffee 1,100 kg NPK/ha
- 30% of manure used for fertilization, 70% sold
- 200 chickens, 12 crossbred cattle for fattening – fed with rice bran, Napier, maize (bran), chicken on concentrates
- Small pension

Results – bio-economic baseline II

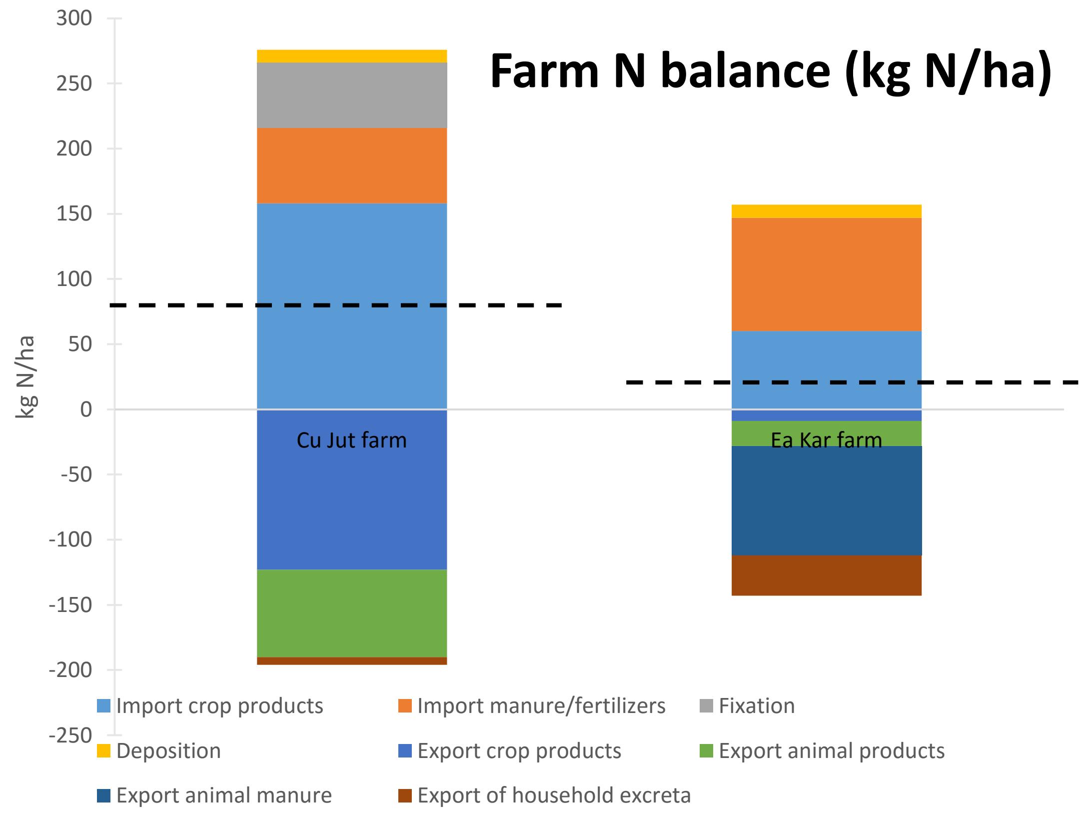
Profitability (USD/farm/year)

		Cu Jut farm	Ea Kar farm
Returns		1. US$	1.
	Gross margin crops	2419.46	5093.24
	Gross margin animals	-2593.42	38.41
Costs			
	Manure/fertilizer costs	180.26	598.07
	Crop protection costs	38	62.59
	Green manure costs	0	0
	Land costs	0	0
	Equipment costs	0	0
	Building costs	0	0
	General costs	0	0
	Hired casual labor costs	30.81	376.74
	Hired regular labor costs	0.2	0
Totals			
	Operating profit (+return farm.labor)	**-423.23**	**4094.25**
	Own labor costs	2954.6	702.82
	Return to own labor	-0.1	3.92
	Home consumption	621.97	551.78
	Off-farm income	6500	323

GHG emissions (t CO2e/farm/year)



Results – bio-economic baseline III



SOM balance (kg/ha)

		Cu Jut farm	Ea Kar farm
Inputs	Root biomass and stubble	464	557
	Surface residue retention	0	0
	Own manure	0	759
	Imported manure	81	0
Outputs	Manure degradation	72	686
	SOM degradation	521	536
	Balance	**-48**	**93**

Results – livestock intensification scenarios I

Profitability (USD/farm/year)

Returns		Baseline	Forage-based cattle fattening sc.	Grain-based cattle fatting sc.
	Gross margin crops	5093.24	4238.99	5481.54
	Risk crop margin	0	0	0
	Gross margin animals	38.41	2837.18	1569.37
Costs				
	Fertilizers/Manure costs	598.07	577.94	165.53
	Crop protection costs	62.59	92.19	49.14
	Green manure costs	0	0	0
	Land costs	0	0	0
	Equipment costs	0	0	0
	Building costs	0	0	0
	General costs	0	0	0
	Hired casual labor costs	376.74	508.37	316.91
	Hired regular labor costs	0	379.11	0
Totals				
	Operating profit (+return farm. labor)	**4094.25**	**5518.56**	**6519.33**
	Change from baseline		35%	59%
	Own labor costs	702.82	702.84	504.08
	Return to own labor	3.92	5.28	5.82
	Home consumption	551.78	211.64	211.64
	Interest costs	0	0	0

SOM balance (kg/ha)

		Baseline	Forage-based cattle fattening sc.	Grain-based cattle fatting sc.
Inputs				
	Root biomass and stubble	557	604	536
	Surface residue retention	0	0	0
	Own manure	759	2377	0
	Imported manure	0	0	0
Outputs				
	Manure degradation	688	2156	0
	SOM degradation	536	536	536
	Erosion losses	0	0	0
Balance				
	Balance	**93**	**290**	**1**
	Change from baseline		212%	-99%

Results – optimization and trade-offs I

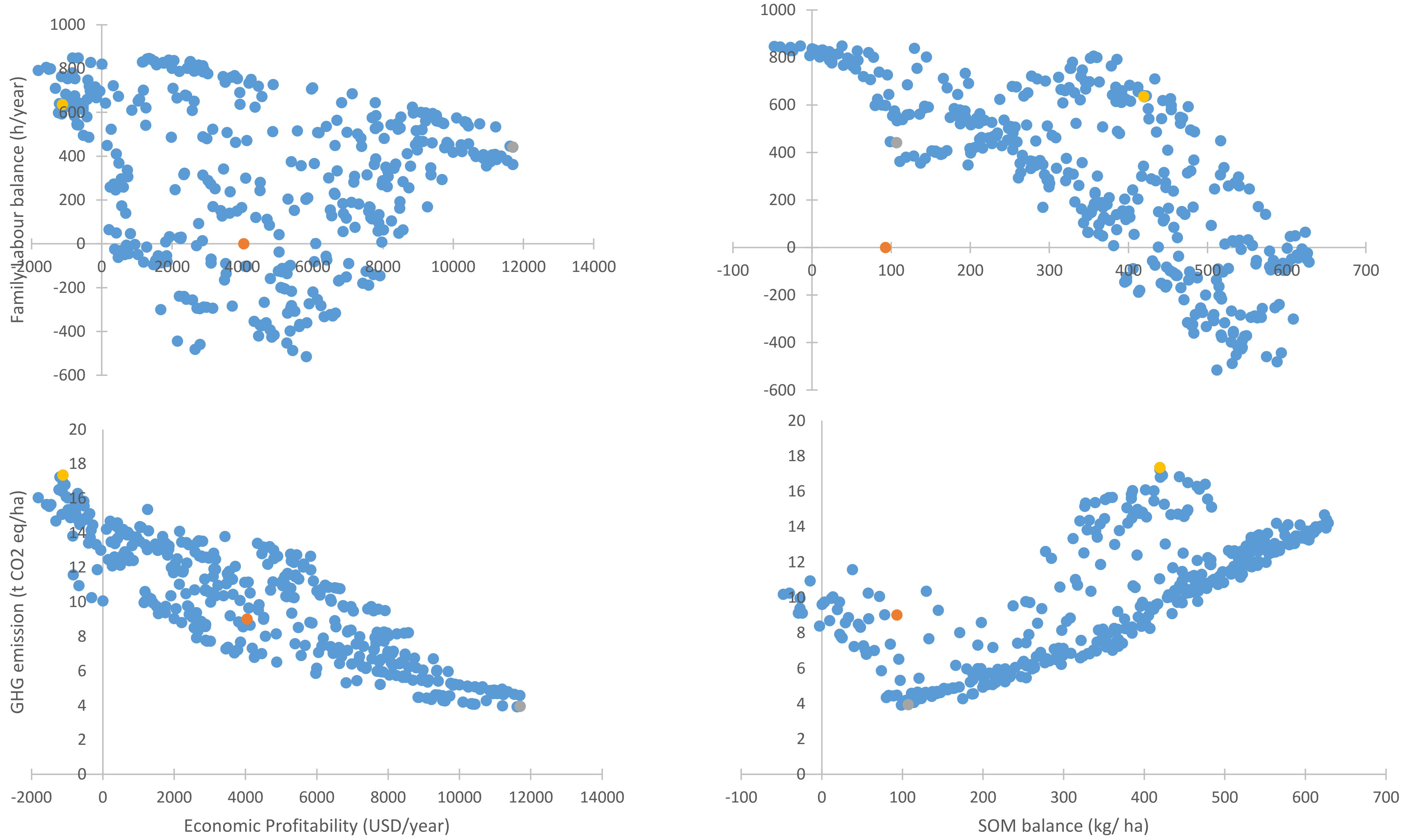
Four objectives set

1. Maximize farm profitability (USD/year)
2. Decrease required labour (hours family labour/year
3. Minimize GHG emissions (kg CO2e/ha/year)
4. Maximize organic matter input to soil (kg OM/ha/year)

Constraints - variables	Current farm value	Possible minimum	Possible maximum
Farm area (ha)	1.7	0.1	1.7
Metabolisable energy balance all year (%)	0.6	-6	5
Crude protein balance all-year (%)	5.3	-10	17
Intake balance all-year (%)	-12.2	-20	0

Decision variables - description	Current farm value (baseline)	Modeling parameters	
		Minimum	Maximum
1. Land adjustment options			
Area of farm planted to maize	0.7 ha	No maize	Entire farm maize only
Area of farm planted to Napier grass	0.3 ha	No Napier	Entire farm Napier only
Area of farm planted to coffee	0.5 ha	No coffee	Entire farm coffee only
Area of farm planted to rice	0.2 ha	No rice	Entire farm rice only
2. Options for the number of cattle and poultry			
Steers for fattening	6 steers	0 head	20 heads
Cows for reproduction	4 cows	0 head	4 heads
Calves	2 calves	0 head	4 heads
Chickens	200 chickens	0 birds	200 birds
3. Cattle feeding options			
Percent of maize grain fed to cattle	100%	0%	100%
Percent of maize residue fed to cattle	100%	0%	100%
Percent of rice straw fed to cattle	90%	0%	100%
Imported cattle feed used	None	None	10 t
Percent of rice bran fed to cattle	100%	0%	100%
Percent of farm-grown Napier grass fed to cattle	100%	0%	100%
Daily average weight gain of steers	0.2 kg/day	0.15 kg/day	0.25 kg/day
4. Manure and residue use options			
Percent of farm yard manure applied to field	31%	0%	100%
Percent of maize residues applied as mulch	0%	0%	100%
Percent of rice residue straw used for bedding	10%	0%	100%

Results – optimization and trade-offs II



Conclusions

- Ea Kar and Cu Jut have different production specializations, farm size, livestock holdings, cash crops, forage cultivation
- Cu Jut farm not profitable in current setup, and subsidized by off-farm income. It also had negative SOM balance (manure export and residue burning)
- Crop residue burning and enteric fermentation largest contributors to relatively high GHG (in East Africa, 0.5 - 5 t CO2e/ha)
- Grain-based (+59%) and forage-based (+35%) cattle fattening both potentially profitable for Ea Kar farm. However, risk of nutrient mining and negative SOM of the first
- Solution spaces exist for increasing profit and SOM while decreasing labour and GHG of the Ea Kar farm. However, trade-offs apparent
- Future: Participatory feedback loop to farmers and stakeholders? Training of partners? Study in other countries? Model ex-post impacts?

Acknowledgements

Birnholz, C., Bolliger, A., Tan Khanh, T., Groot, J., Paul, B. (2017). Bio-economic evaluation and optimization of livestock intensification options in the Central Highlands of Vietnam. *Working Paper No. 433. International Center for Tropical Agriculture (CIAT)*, Nairobi, Kenya. 31 p. http://hdl.handle.net/10568/79446

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Headquarters
Km 17 Recta Cali-Palmira C.P. 763537
P.O. Box 6713, Cali, Colombia
Phone: +57 2 445 0000

ciat@cgiar.org
www.ciat.cgiar.org

ciat.ecoefficient

@ciat_cgiar

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